



## 2006 STATE OF THE OCEAN: PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE NEWFOUNDLAND AND LABRADOR REGION

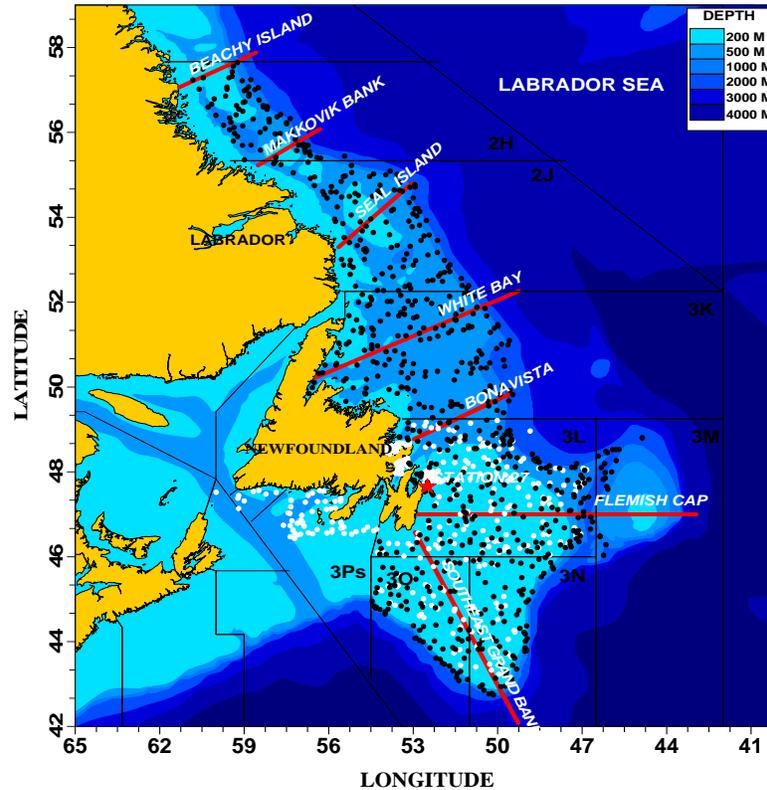


Fig. 1. Location Map showing the positions of standard sections (red lines), the fixed AZMP monitoring site (Station 27, red dot) and the positions of oceanographic observations made during spring (white dots) and fall (black dots) fisheries assessment surveys in the Newfoundland and Labrador Region during 2006.

### Context

The physical oceanographic environment influences the yield (growth, reproduction, survival), and behaviour (distribution, catchability, availability) of marine organisms as well as the operations of the fishing industry. Changes in this environment may contribute directly to variations in food source (plankton), resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass as well as influencing the perception of the resource status and the efficiency and profitability of the industry.

Physical oceanographic conditions are therefore measured during research vessel resource surveys and regularly at fixed sites as part of the **Atlantic Zonal Monitoring Program (AZMP)**. Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, research studies, ships-of-opportunity, fishing vessels and remote sensing (satellites). All of the hydrographic data are edited and archived in a database at Canada's national Integrated Scientific Data Management (ISDM) branch in Ottawa. A working copy is maintained in a regional database at the Northwest Atlantic Fisheries Centre (NAFC) in St. John's Newfoundland.

## SUMMARY

- Annual air temperatures were above normal in Newfoundland and Labrador by 2.9°C (record high) at Cartwright, 2°C (record high) at Bonavista and by nearly 1°C at St. John's.
- Annual sea ice extent remained below normal for the 12<sup>th</sup> consecutive year on the Newfoundland and Labrador Shelf. The ice extent was the 4<sup>th</sup> lowest in winter and the lowest during spring since 1963.
- No icebergs were detected south of 48°N on the Northern Grand Bank and only 11 during 2005, the lowest numbers since 1966, well below the 106-year average of 477.
- The Station 27 0-175 m depth-averaged annual water temperature increased to 0.9°C above normal, the highest of the 61-year record.
- Annual surface temperatures at Station 27 reached 1.7°C above normal, also the highest in 61 years.
- Bottom temperatures at Station 27 have been above normal for the past 11 years. In both 2005 and 2006 they were 0.8°C above normal, the 3<sup>rd</sup> highest in the 61-year record.
- Near surface (0-50 m) annual salinities at Station 27 were above normal for the 5<sup>th</sup> consecutive year.
- The area of <0°C (CIL) water mass on the eastern Newfoundland Shelf off Cape Bonavista during 2006 was below normal for the 12<sup>th</sup> consecutive year and the 3<sup>rd</sup> lowest since 1948.
- Bottom temperatures during the fall of 2006 on the Newfoundland and Labrador Shelf were above normal in most areas but decreased substantially from 2005, particularly off Southern Labrador.
- The area of bottom on the Grand Banks covered by sub-zero water has decreased from >50% during the first half of the 1990s to near 15% during the past 3 years, ranking the 3<sup>rd</sup> lowest in 2006.

## INTRODUCTION

The ocean environment on the Newfoundland and Labrador Shelf is influenced by several factors including the Labrador Current, cross-shelf exchange with warmer continental slope water and bottom topography. Superimposed on these oceanic processes are large seasonal and inter-annual variations in solar heat input, ice cover and storm-forced mixing. The resulting water mass on the shelf is characterised by large annual cycles with strong horizontal and vertical temperature and salinity gradients. Water properties are monitored extensively by fisheries assessment and oceanographic research surveys throughout the year (Fig. 1). Some of these observations are expressed as differences or anomalies from their long-term average values. Where possible, the long-term averages are standardised to a base period of 1971-2000, sometimes referred to as the normal.

## 2006 ASSESSMENT

### Meteorological and Ice Conditions

Monthly air temperatures at both Cartwright Labrador and St. John's were above normal during all months of 2006 (Fig. 2). Annual air temperatures were above normal in both Newfoundland and Labrador by 2.9°C at Cartwright and 1°C at St. John's. Since the 1960s, annual air temperature anomalies at Cartwright (Fig. 2) showed large variations, superimposed on a general downward trend through to the early 1990s. This was followed by a general rise in air temperatures through to the end of the 1990s and into the early 2000s. During 1999 for example, temperature anomalies of 1.9°C above normal set an all time high at St. John's (126-year record); and in 2006 the annual anomaly of 2.9°C at Cartwright was the highest in the 73-year record. Air temperatures at Cartwright have been above normal for the past 11 years and at St. John's for the past 8 years.

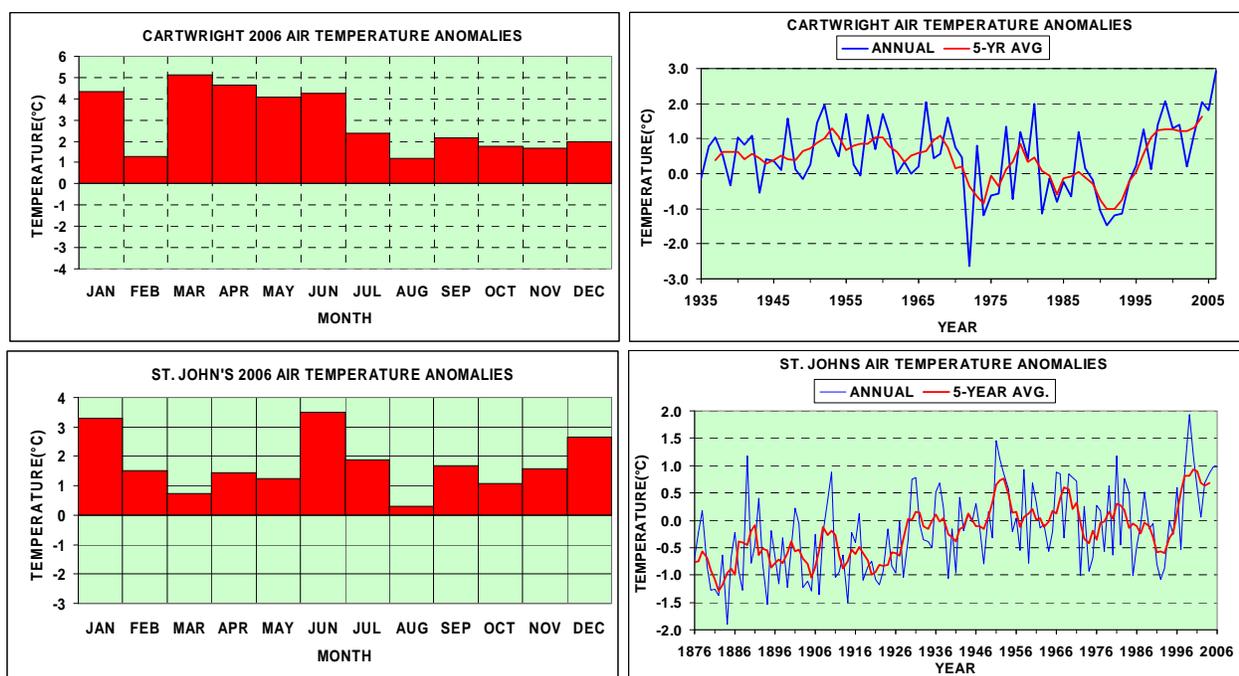


Fig 2. Departures from normal monthly mean air temperatures at Cartwright and St. John's for 2006 (left panels) and departures from normal annual means (blue line) and the 5 year means (red line) at Cartwright and St. John's (right panels).

Monthly sea-ice extent on the Newfoundland and southern Labrador Shelf south of 55°N latitude were well below normal in all months of the ice season (Fig. 3). By May, the ice extent had decreased to very low values and by June sea-ice had disappeared completely. The duration of the sea ice season was shorter than normal during 2006. Sea-ice extent decreased compared to 2005, remaining below normal for the 12<sup>th</sup> consecutive year. The extent of sea ice during the winter of 2006 was the 4<sup>th</sup> lowest in the 43-year record, whereas in the spring it was the lowest on record.

No icebergs were detected south of 48°N on the Northern Grand Bank in 2006 and only 11 during 2005 (Fig. 3). These were the lowest numbers since 1966, well below the 106 year average of 477. The highest number of icebergs normally occurs in May with just over 200. In 2004 there were 262 icebergs observed on the Northern Grand Bank and in some years of the early 1990s, over 1500 icebergs drifted onto the northern Grand Bank.

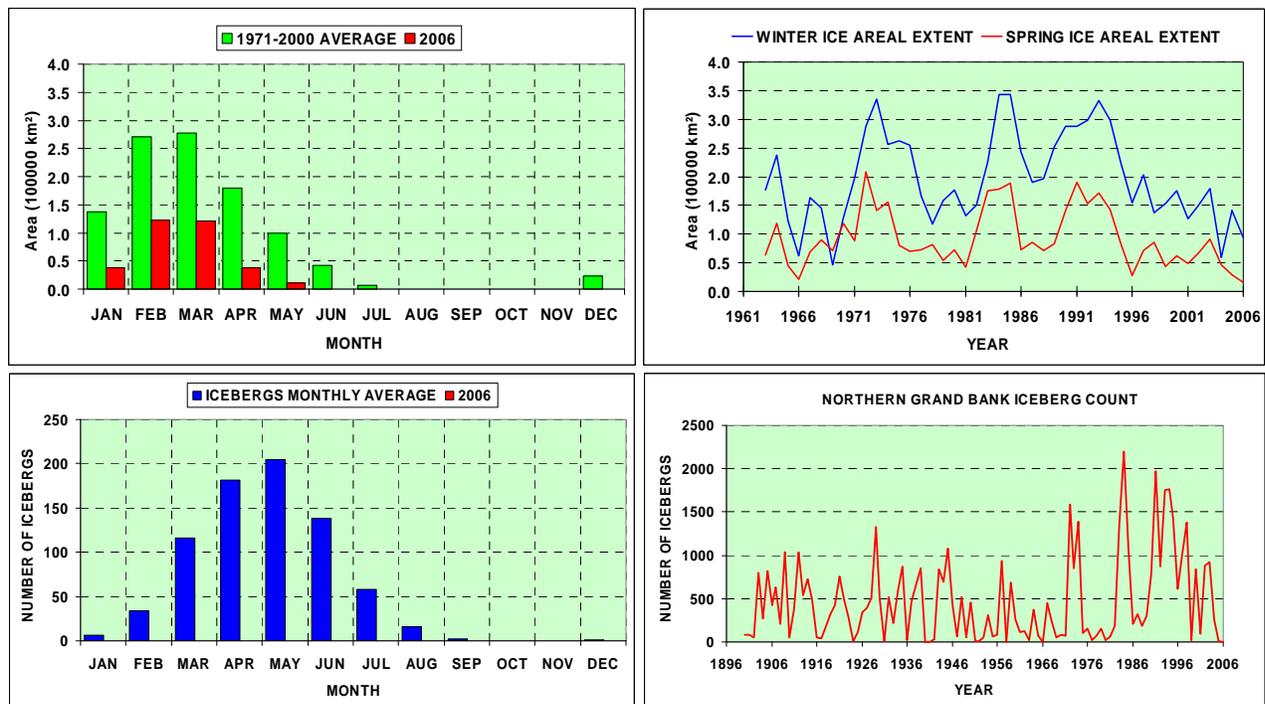


Fig. 3. Monthly and seasonal (winter and spring) sea-ice extent off Newfoundland and southern Labrador (top panels) and monthly and annual iceberg counts for the northern Grand Banks (Bottom panels). No icebergs were detected in 2006.

## Temperature and Salinity Variability

### AZMP Fixed Site (Station 27)

Temperature and salinity conditions have been measured at a standard hydrographic monitoring station (Station 27, bottom depth 176 m) off Cape Spear, about 7 km from St. John's Harbour, since 1946 (Fig. 1). In 2006 upper layer temperatures at this site, which is located in the inshore branch of the Labrador Current, were generally less than 1°C from February to mid-April and from approximately 0°C to -1°C throughout the year near the bottom. By late April upper layer temperatures had warmed to >1°C and to above 15°C by August, after which the fall cooling commenced. Temperatures were about 1°-1.5°C above normal during the winter months over most depths and increased to 2°-3°C above normal in the upper water column during the summer. A slightly colder than normal anomaly occurred at 50 m during June and again in November at 75 m (Fig. 4).

Annual surface water temperatures were 1.7°C above normal, the highest in the 61-year record; bottom temperatures were above normal by 0.8°C, the 3<sup>rd</sup> highest in the 61-year record and the depth averaged (0-175 m) temperatures were above normal by 0.9°C also the highest in the 61-year record (Fig. 5). The Station 27 depth-averaged annual temperature (which is proportional to the total heat content) shows large annual and decadal fluctuations throughout the time series (Fig. 5). From 1950 to the late 1960s, the total heat content was generally above the long-term mean. Recently, the heat content varied from a record low in 1991, to very high during 1996 and to a record high during 2006.

Maximum surface salinities at Station 27 (Fig. 4) during early spring were  $>32.4$  while minimum values of  $<31.2$  occurred during September to November. At mid depths, salinities ranged from 32.2 to 32.8 and near the bottom, from 33-33.4. Salinity values were above normal near the surface during the summer months and at mid depths in November and December, otherwise they were near normal.

The 0-50 m depth-averaged summer salinity anomalies show similar patterns as the heat content with fresher-than-normal periods generally corresponding to the colder-than-normal conditions (Fig. 5). Since the fresh conditions of the early 1990s, salinities have fluctuated above and below normal. During 2002, summer salinities on the Newfoundland Shelf increased to the highest values in about 12 years. The 2003 to 2005 values remained above the long-term mean with the 2006 value very similar to 2005, above normal for the 5<sup>th</sup> consecutive year.

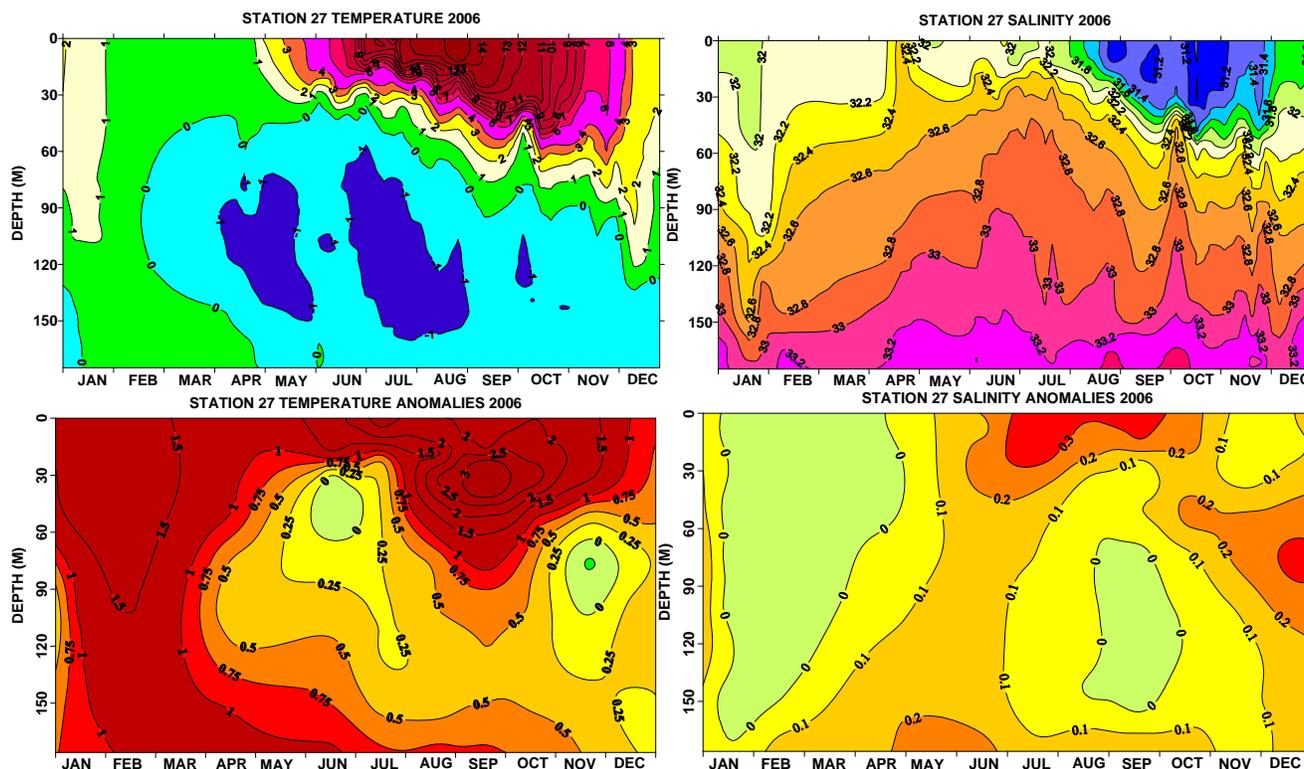


Fig. 4. Contours of temperature and salinity (top panels) and their anomalies (bottom panels) at Station 27 as a function of depth for 2006.

### AZMP Standard Sections

Summer monitoring of temperature and salinity along several standard sections across the Newfoundland and Labrador Shelf began in the late 1940s and early 1950s (Fig. 1). In 1998, under the Atlantic Zone Monitoring Program (AZMP), sampling along the sections was expanded to include biological and chemical measurements; several sections are now sampled seasonally.

The water mass characteristics observed along the standard sections are typical of sub-polar waters with sub-surface temperatures ranging from  $-1^{\circ}$  to  $2^{\circ}\text{C}$  and salinities from 32 to 33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region. This water mass is warmer and saltier than the sub-polar shelf waters with temperatures ranging from  $3^{\circ}$  to  $4^{\circ}\text{C}$  and salinities from 34 to 34.75. Surface temperatures warm to  $10^{\circ}$  to  $12^{\circ}\text{C}$  during summer, while bottom temperatures over most of the shelf range from  $1^{\circ}$  to  $4^{\circ}\text{C}$ . Throughout most

of the year, the cold relatively fresh water overlying the shelf is separated from the warmer higher density water of the continental slope region by a strong temperature and density front. In general, water properties along the standard sections undergo seasonal modification due to the seasonal cycles of air-sea heat flux, wind forced mixing and sea-ice formation and melting, which leads to intense vertical and horizontal changes or gradients (Fig. 6).

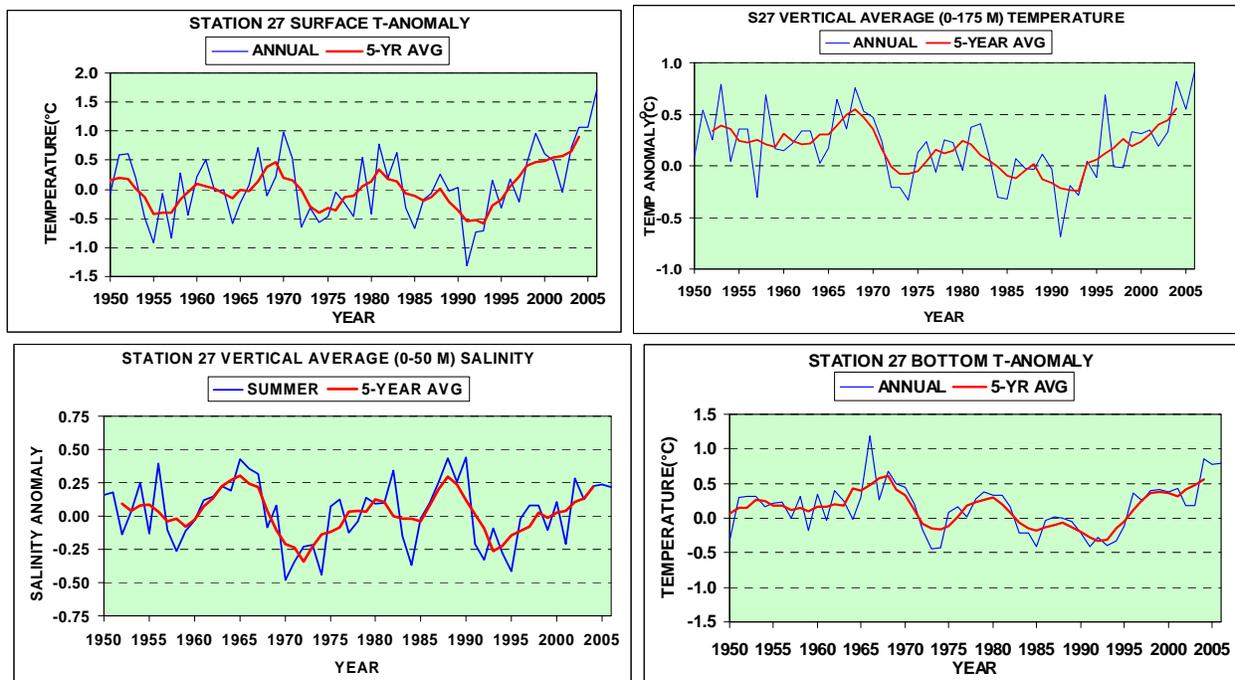


Fig. 5. Departures from normal surface, bottom and depth averaged (0-176 m) Station 27 temperature and upper layer depth averaged salinity.

The most revealing feature of the temperature structure on the Newfoundland and Labrador Shelf, particularly during the summer, is the layer of cold  $<0^{\circ}\text{C}$  water, commonly referred to as the Cold Intermediate Layer (CIL). This winter-cooled water mass remains isolated during the summer and early fall months between the seasonally heated surface layer and warmer near bottom water originating from the continental slope region. Along the Bonavista section during the summer the CIL normally extends offshore by over 200 km, with a maximum vertical extent of about 200 m. In 2006, this water mass extended to near the surface during spring, had the 3<sup>rd</sup> smallest cross sectional area since 1948 in the summer and was still present at mid-depths by late November. Seasonal cross sections of salinity show remarkable similarities from spring to fall with slightly fresher upper-layer shelf values occurring during the summer (Fig. 6).

The time series of CIL area and mean temperature for eastern Newfoundland (Bonavista section) and southern Labrador (Seal Island) are displayed in Fig. 7. Low CIL areas correspond to warm oceanographic conditions. The CIL area during 2006 was below the long-term mean along all sections sampled from Labrador to southern Newfoundland. Along the Bonavista section, the CIL was below normal for the 12<sup>th</sup> consecutive year ranking 3<sup>rd</sup> lowest in 58 years of observations. These values are in sharp contrast to the near record high values measured during the extremely cold years of the early 1990s on the Newfoundland Shelf. The temperature time series for both Newfoundland and Labrador show a continuation of the increasing trend since the early 1990s with the 2006 value the 3<sup>rd</sup> highest off eastern Newfoundland surpassed only by 2004 and 1965 (Fig. 7).

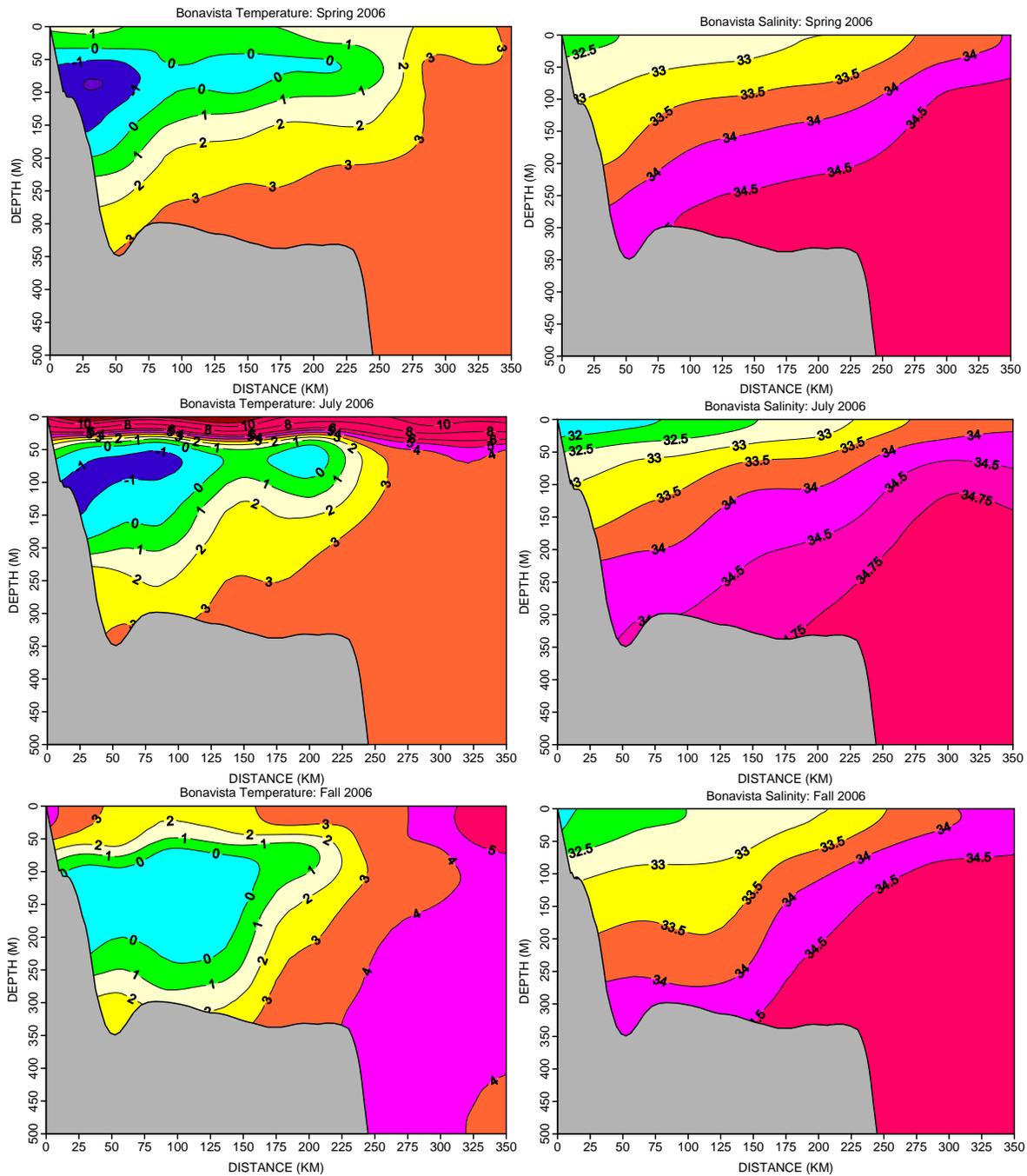


Fig. 6. Cross sectional contour maps of the temperature structure on the Eastern Newfoundland Shelf off Cape Bonavista during the spring, summer and fall of 2006.

### Multi-Species Survey Results

The collection of oceanographic data aboard fisheries resource assessment surveys was initiated in 1971 in the Newfoundland and Labrador Region. These data are routinely used by fisheries scientists and oceanographers to monitor changes in the near-bottom thermal habitat of many marine fish and invertebrate species. The data are also used to relate variations in the distribution and abundance of groundfish species to changes in the ocean environment. Two standardized trawl surveys are conducted each year by Fisheries and Oceans in the Newfoundland and

Labrador Region, one in the spring in NAFO areas 3PLNO and one in the fall in areas 2J3KLNO (Fig. 1).

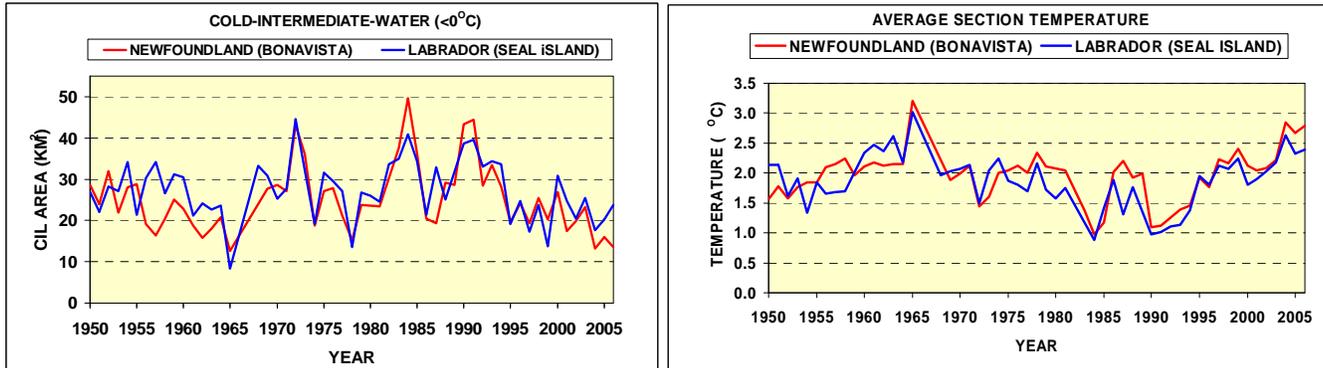


Fig. 7. Time series of the Cold-Intermediate Layer (CIL) areas and the average temperature and salinity along the Bonavista Section off eastern Newfoundland and the Seal Island Section of southern Labrador. See Fig. 1 for locations.

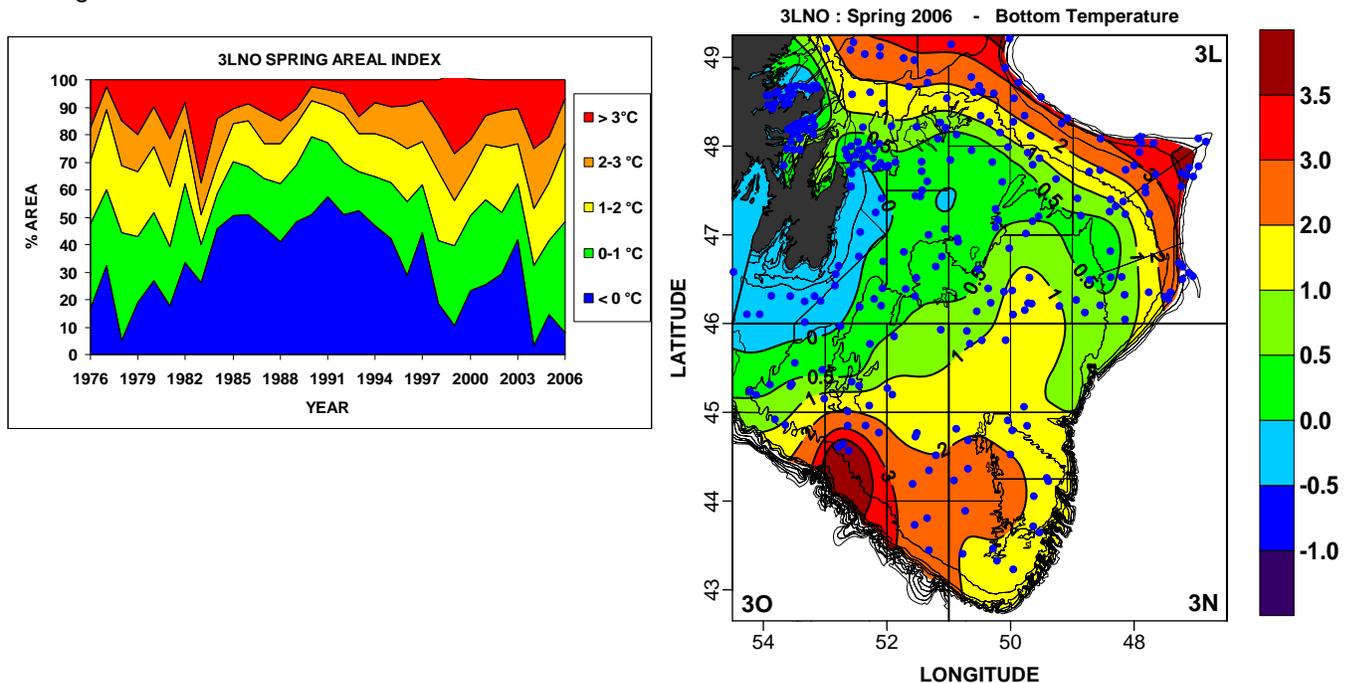


Fig. 8. Bottom temperature map (°C) for the spring of 2006 for NAFO Divisions 3LNO and the percentage area of the bottom covered by water in different temperature ranges.

A bottom temperature map for NAFO Divisions 3LNO during the spring of 2006 is displayed in Fig. 8 along with the percentage area of the bottom habitat covered with water in different temperature ranges. Spring bottom temperatures in Div. 3L ranged from <0°C to 0.5°C in the inshore regions of the Avalon Channel and parts of the Grand Bank and from 1° to >3°C at the shelf edge. Over the central and southern areas bottom temperatures ranged from 1°C to 3.5°C. The spring of 2006 had the 3<sup>rd</sup> lowest area of <0°C water in Division 3L since the surveys began in the early 1970s (Fig. 8). In general, temperatures were above normal in most areas of the Grand Banks by 0.5°C to 1°C.

A bottom temperature map for the fall of 2006 in NAFO Divisions 2J, 3K and 3LNO is displayed in Fig. 9. Bottom temperatures in Div. 2J ranged from <0°C inshore, to >3.5°C offshore at the shelf

break. Over Hamilton Bank, they ranged from 0°C to 2°C, up to 1°C above the long-term average in some areas. The long-term average bottom temperature during the fall in Div. 2J is slightly over 2°C but during the latter half of the 1990s, it increased to about 2.5°C and to 3°C during 2003 to 2005. The average bottom temperature during 2006 decreased compared to the 2005 value but remained above the long-term average (Fig. 9).

Most of the 3K region is deeper than 200-m. As a result, relatively warm slope water floods through the deep troughs between the northern Grand Bank and southern Funk Island Bank and between northern Funk Island Bank and southern Belle Isle Bank. Bottom temperatures on these banks during the fall of 2006 ranged between 2° to 3°C and were generally <1°C in the near-shore areas. Near the edge of the continental shelf in water depths >500 m, temperatures were near normal around 3.5°C. The time series of the average bottom temperature in Div. 3K (Fig. 9) during the fall ranged from 1°C in 1982 to 2.3°C in 1986 with an overall average of slightly <2°C. From 1995 to 1999, it increased to above-average reaching a maximum of 2.7°C during 1999. Averaged bottom temperatures in all divisions increased to near-record highs in 2004 and 2005 but decreased significantly in 2006.

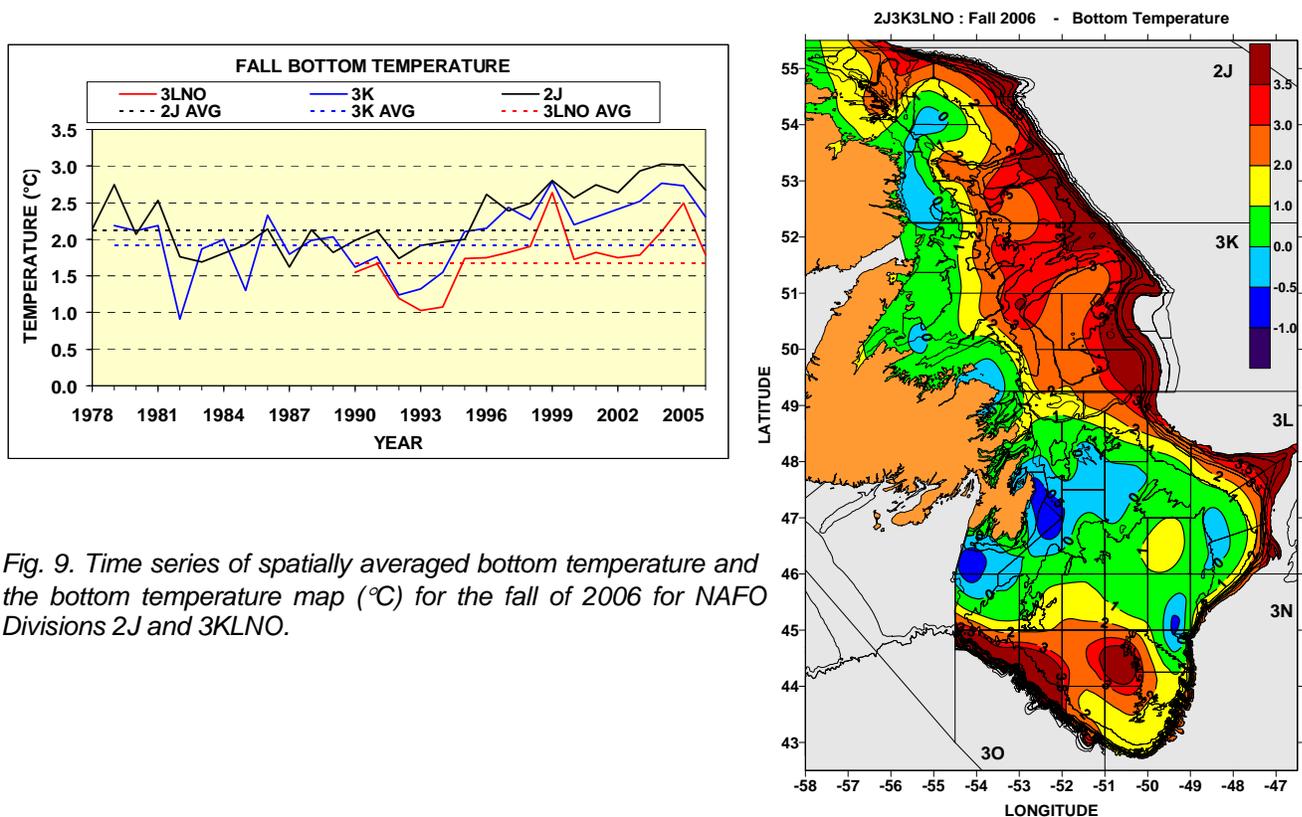


Fig. 9. Time series of spatially averaged bottom temperature and the bottom temperature map (°C) for the fall of 2006 for NAFO Divisions 2J and 3KLNO.

Fall bottom temperatures in Div. 3LNO generally ranged from <0°C on the northern Grand Bank and in the Avalon Channel to 3.5°C along the shelf edge. Over the southern areas, bottom temperatures ranged from 1° to 3.5°C during 2006 and to >3.5°C along the edge of the Grand Bank. During 2006 bottom temperatures were predominately above normal on the northern Grand Bank but varied about the mean in southern areas. The spatially averaged bottom temperature in Divs. 3LNO during the fall decreased from approximately 1.5°C during 1990 to 1°C during 1993 and 1994 then increased to approximately 1.8°C during 1995. These remained relatively constant up to 1998 but then increased to >2.5°C during 1999, the highest in the 10 year record. During the fall of 2000 to 2003 the mean bottom temperature decreased by nearly 1°C over the 1999 value, but was still above the cold conditions of the early 1990s. In 2005 temperatures again increased

by about 0.5°C reaching 2.5°C, the 2<sup>nd</sup> highest in the time series. In 2006, they decreased to near average values (Fig. 9).

## CONCLUSION

The large-scale atmospheric circulation pattern in the North Atlantic during 2006 resulted in weaker-than-normal arctic outflow to the region causing record high annual air temperatures in some locations and above normal values throughout the Northwest Atlantic from West Greenland to Baffin Island to Labrador and Newfoundland. Sea-ice extent and duration on the Newfoundland and Labrador Shelf remained below average for the 12<sup>th</sup> consecutive year. Consequently, water temperatures in the region remained well above normal in 2006, reaching a 61-year high at Station 27 off eastern Newfoundland. These conditions represent a continuation of the warm trend experienced since the mid-to-late 1990s. The annual temperature values for 2006 increased over 2005 values even surpassing the near-record highs of 2004. However, data from late fall surveys of 2006 showed a slight decrease in sub-surface temperatures as somewhat colder water moved southward over the area. Salinities on the Newfoundland and Labrador Shelf, which were lower than normal throughout most of the 1990s, increased to the highest observed in over a decade during 2002 and have remained above normal during the past 5 years.

## Outlook for 2007

Oceanographic conditions in the Newfoundland and Labrador region of the Northwest Atlantic are largely determined by the strength of the winter atmospheric circulation over the Northwest Atlantic and local air temperatures. A circulation pattern that promotes the flow of cold Arctic air southward results in extensive sea-ice along the coast and generally cold and fresh ocean conditions during spring and summer. On the other hand, when the circulation is weak the reverse is generally true leading to warm-saline ocean conditions. Early indications during the winter of 2006/2007 show significant positive anomalies in air temperatures over Labrador (+3.7°C in January and +3.3°C in February at Cartwright) and Newfoundland (+2.2°C in January and -0.7°C in February at St. John's). This has led to delayed sea-ice formation on the Newfoundland and Labrador Shelf with generally lower than average coverage continuing into the winter of 2007. However, sea ice appears more extensive than in 2006. In addition, the atmospheric pressure fields during the December-February 2007 period indicate a very large area of below normal values over northern regions that may enhance arctic outflow during late winter. Therefore, we can expect some cooling in ocean temperatures throughout the Newfoundland and Labrador Region, particularly during the spring of 2007.

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## FOR MORE INFORMATION

Contact: E. B. Colbourne  
P.O. Box 5667  
St. John's, NL A1C 5X1  
Tel: (709) 772-6101  
Fax: (709) 772-4105  
E-Mail: [colbourn@dfo-mpo.gc.ca](mailto:colbourn@dfo-mpo.gc.ca)

This report is available from the:

Center for Science Advice  
Newfoundland and Labrador Region  
Fisheries and Oceans Canada  
PO Box 5667  
St. John's, NL A1C 5X1

Telephone: (709) 772-8892/2302

Fax: (709) 772-6100

E-Mail: [wellsn@dfo-mpo.gc.ca](mailto:wellsn@dfo-mpo.gc.ca)

Internet address: [www.dfo-mpo.gc.ca/csas](http://www.dfo-mpo.gc.ca/csas)

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